

REMARKS

Reconsideration and allowance of the present patent application based on the following remarks are respectfully requested.

By this Amendment, claim 15 is amended and claim 17 is newly added. Support for the amendment to claim 15 can be found throughout the original disclosure. No new matter has been added. Accordingly, after entry of this Amendment, claims 1-3, 5-6, 13 and 15-17 will be pending in the patent application.

Claim 15 was objected to because of an informality noted in the Office Action. In response, claim 15 has been amended in the manner suggested by the Office Action. Accordingly, reconsideration and withdrawal of the objection to claim 15 are respectfully requested.

Claim 15 was rejected under 35 U.S.C. §102(e) based on Callegari *et al.* (U.S. Pat. No. 6,664,186) (hereinafter "Callegari"). The rejection is respectfully traversed.

Claim 15 recites a barrier structure for copper metallization structure, comprising, *inter alia*, "a first Ru layer disposed between the dielectric pattern and the Cu layer; an oxide film disposed between the first Ru layer and the Cu layer; and a second Ru layer disposed between the oxide film and the Cu layer, wherein the oxide film is made of Ru_xO_y, and wherein the oxide film is disposed directly on an upper surface of the first Ru layer, and the second Ru layer is disposed directly on an upper surface of the oxide film." The cited portions of Callegari do not disclose, teach or suggest these aspects of claim 15.

By way of review, the cited portions of Callegari disclose a trench capacitor that is formed on a substrate 30. The trench capacitor includes successively an optional conductive barrier layer 32, a bottom electrode layer 33, a dielectric layer 34, a top electrode layer 35, an optional dielectric layer buffer layer 36, a diffusion barrier 81 and a metallization barrier 82. *See* Callegari at FIG. 28. The optional conductive barrier layer 32 (identified by the Office Action as "the first Ru layer" of claim 15) may include Ru or RuO₂. *See* Callegari at col. 15, lines 9-16. The bottom electrode layer 33 (identified by the Office Action as "the oxide film" of claim 15) may include RuO₂. *See* Callegari at col. 15, lines 16-19. The top electrode layer 35 (identified by the Office Action as "the second Ru layer" of claim 15) may include Ru. *See* Callegari at col. 15, lines 39-43.

With this said, the cited portions of Callegari do not disclose, teach or suggest that the top electrode layer 35 (identified by the Office Action as "the second Ru layer" of claim 15) is directly formed on the bottom electrode layer 33 (identified by the Office Action as "the

oxide film” of claim 15). Specifically, the cited portions of Callegari are silent as to a second Ru layer disposed directly on an upper surface of the oxide film. Callegari merely discloses that the top electrode layer 35 (identified by the Office Action as “the second Ru layer” of claim 15) is formed directly on the dielectric layer 34 that includes aluminum oxide. *See* Callegari at FIG. 28 and col. 15, lines 20-23. Therefore, Applicant respectfully submits that the cited portions of Callegari do not disclose, teach or suggest each and every feature recited in claim 15 and, as a result, cannot anticipate this claim.

Accordingly, reconsideration and withdrawal of the rejection of claim 15 under 35 U.S.C. §102(e) based on Callegari are respectfully requested.

Claims 1-3, 5, 6, 13, 15 and 16 were rejected under 35 U.S.C. §103(a) based on Omstead (U.S. Pat. No. 6,713,373) in view of Chyan *et al.* (U.S. Pub. No. 2004/0051117) (hereinafter Chyan). The rejection is respectfully traversed.

Claim 1 recites a barrier structure for copper metallization, comprising, *inter alia*, “...a first Ru layer disposed directly on an upper surface of the dielectric pattern; an oxide film disposed directly on an upper surface of the first Ru layer; a second Ru layer disposed directly on an upper surface of the oxide film; and a Cu layer disposed directly on an upper surface of the second Ru layer...” The cited portions of Omstead and Chyan do not present a *prima facie* case that renders claim 1 obvious.

By way of review, the cited portions of Omstead disclose a glue layer interposed between a diffusion barrier (on a dielectric barrier) and a conductive layer. *See* Omstead at col. 3, lines 33-36. The glue layer consists of a RuO_x/Ru bilayer which provides adhesion to the dielectric through RuO_x and to the copper through Ru. *See* Omstead at col.4, lines 15-36 and col. 6, lines 7-10. The cited portions of Omstead further disclose that, in an alternative embodiment, a barrier layer may be placed between the dielectric and the RuO_x layer. *See* Omstead at col. 6, lines 11-12. Omstead cites tantalum nitride as one of the materials that can be used for the barrier layer. *See* Omstead at col. 6, lines 13-14.

The Office concedes that the cited portions of Omstead do not disclose, teach or suggest that the barrier layer is a Ru layer. *See* Office Action at page 3. The Office relies on Chyan as allegedly disclosing, teaching or suggesting the use of Ru as an alternative to TaN for the barrier layer. *See* Chyan at paragraph 23. The Office then concludes that it would have been obvious to substitute the Ru barrier layer of Chyan for the TaN barrier layer of Omstead. *See* Office Action at page 4. Applicant respectfully disagrees.

In accordance with the invention of claim 1, the Ru/Ru_xO_y/Ru multilayer structure is

used as a barrier structure for copper metallization. The Ru_xO_y acts as a stuffing barrier for the copper layer, and the Ru layers are used as sacrificial barriers for the copper layer. The Ru_xO_y stuffing barrier, which has a composition that remains unchanged, prevents the diffusion of copper into the dielectric layer. The sacrificial barrier is a barrier that suppresses the diffusion of copper by changing the composition thereof. As a result, and as explained in the present application, a barrier structure including Ru/ Ru_xO_y /Ru layers has a higher electric conductivity and also improved barrier characteristics, compared to conventional Cu diffusion barriers. *See* Application at page 2, lines 16-22 and page 4, lines 1-10. Moreover, a deterioration of the barrier characteristics is reduced. *Id.* As explained in the present application, Applicant has determined that it is critical to provide a barrier structure for copper metallization that is less prone to deterioration and has excellent barrier characteristics and conductivity. *Id.* Applicant has determined that the use of a Ru/ Ru_xO_y /Ru multilayer structure provides unexpected results in terms of electric conductivity and copper diffusion barrier, as opposed to a TaN structure. *See* Application at page 4, lines 1-10. None of these aspects are discussed in the cited portions of Omstead. Accordingly, Applicant respectfully submits that claim 1 is not obvious in view of Omstead and Chyan. *See* MPEP 716.02(a) "Presence of a property not possessed by the prior art is evidence of nonobviousness", citing In re Papesch, 315 F.2d 381, 137 USPQ 43 (CCPA 1963).

Further, the cited portions of Omstead recognize the use of RuO_x /Ru bilayer as a "glue" layer to glue Cu onto the dielectric. *See* Omstead at col. 3 line 33-36 and col. 4, line 15-36. While Omstead does disclose that a TaN barrier layer may be positioned between the dielectric layer and the RuO_x layer, this configuration appears to be less desirable in view of Omstead's own teachings because it would reduce the adhesion between the copper layer and the dielectric layer. *See* Omstead at col. 6, lines 8-10 "[t]he bilayer provides adhesion to the dielectric through RuO_x and to the copper through Ru." In view of this, Applicant respectfully submits that one skilled in the art would not be motivated to provide a layer, let alone a Ru layer, between the dielectric layer and the RuO_x , as recited in claim 1.

Therefore, for at least these reasons, Applicant respectfully submits that claim 1 is not obvious in view of the combination of Omstead and Chyan.

Claims 2-3, 5, 6, 13 are patentable over the cited portions of Omstead, Chyan and any proper combination thereof at least by virtue of their dependency from claim 1 and for the additional features recited therein.

Claim 15 is patentable over the cited portions of Omstead, Chyan and any proper combination thereof for at least similar reasons as provided above for claim 1 and for the

features recited therein. For example, the combination of Omstead and Chyan does not render obvious a barrier structure for copper metallization structure, comprising, *inter alia*, “a first Ru layer disposed between the dielectric pattern and the Cu layer; an oxide film disposed between the first Ru layer and the Cu layer; and a second Ru layer disposed between the oxide film and the Cu layer, wherein the oxide film is made of RuxOy, and wherein the oxide film is disposed directly on an upper surface of the first Ru layer, and the second Ru layer is disposed directly on an upper surface of the oxide film.”

Claim 16 is patentable over the cited portions of Omstead, Chyan and any proper combination thereof at least by virtue of its dependency from claim 15 and for the additional features recited therein.

Accordingly, reconsideration and withdrawal of the rejection of claims 1-3, 5, 6, 13, 15 and 16 under 35 U.S.C. §103(a) based on Omstead in view of Chyan are respectfully requested.

Claims 16 was rejected under 35 U.S.C. §103(a) based on Callegari in view of Zurcher *et al.* (U.S. Pat. No. 6,344,413) (hereinafter “Zurcher”). The rejection is respectfully traversed.

Claim 16 is patentable over the cited portions of Callegari at least by virtue of its dependency from claim 15 and for the additional features recited therein.

The cited portions of Zurcher fail to remedy the deficiencies of Callegari. The cited portions of Zurcher disclose a method for forming a capacitor that includes a first capacitor electrode layer 70, a capacitor dielectric layer 75 and a second capacitor electrode layer 80. *See* Zurcher at FIG. 7. With this said, the cited portions of Zurcher do not disclose, teach or suggest a barrier structure for copper metallization structure, comprising, *inter alia*, “a first Ru layer disposed between the dielectric pattern and the Cu layer; an oxide film disposed between the first Ru layer and the Cu layer; and a second Ru layer disposed between the oxide film and the Cu layer, wherein the oxide film is made of RuxOy, and wherein the oxide film is disposed directly on an upper surface of the first Ru layer, and the second Ru layer is disposed directly on an upper surface of the oxide film”, as recited in claim 16. Therefore, any proper combination of the cited portions of Zurcher and Callegari cannot result, in any way, in the invention of claim 16.

Accordingly, reconsideration and withdrawal of the rejection of claim 16 under 35 U.S.C. §103(a) based on Callegari in view of Zurcher are respectfully requested.

Claim 17 is newly added to define additional subject matter that is novel and non-obvious. Claim 17 is patentable over the art of record for at least similar reasons as provided above for claims 1 and 15.

In view of the foregoing, the claims are now believed to be in form for allowance, and such action is hereby solicited. If any point remains in issue which the Examiner feels may be best resolved through a personal or telephone interview, please contact the undersigned at the telephone number listed below.

Please charge any fees associated with the submission of this paper to Deposit Account Number 033975. The Commissioner for Patents is also authorized to credit any over payments to the above-referenced Deposit Account.

Respectfully submitted,

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